

REVIEW OF SOVIET/EASTERN EUROPEAN RESEARCH ON HEALTH ASPECTS OF MICROWAVE RADIATION*

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THIS paper will discuss the health aspects of microwave radiation in the Soviet Union and other Eastern European countries and, in some cases, will compare their approaches and views to those in the United States and Western countries. Most of the discussion will deal with research, reported human effects, and allowable safe levels of exposure in the Soviet Union because I am more familiar with the situation in the Soviet Union than in other Eastern European countries. I shall also report on the increased interchange and interaction between Soviet and Eastern European scientists and American scientists over the past seven years. This discussion will include a review of the U.S.-U.S.S.R. cooperative program on the biological effects of microwave radiation.

It would be convenient to talk about the Soviet research as if it were composed of a single approach. Generalities can be found in some features of their microwave research program, but their research methodology is as varied as those in the United States. The particular approach to a problem depends on the investigator, the institute performing the research, or both. I shall present some general statements to describe Soviet and Eastern European thinking concerning the health aspects of microwave radiation. It must be realized that these are my impressions and understandings after six visits to the Soviet Union, and that such a presentation oversimplifies a complex subject.

WESTERN AND EASTERN SCIENTIFIC EXCHANGE

For many years literature from the Soviet Union and other Eastern

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European countries have reported biological effects of microwave radiation on humans and animals at low levels of exposure (less than 10 mW/cm.²). Although effects on almost all biological systems were reported, most changes dealt with alterations in the nervous system and behavior. Unfortunately, the Soviet literature in general does not provide details of experimental design and research methodology. The normal research paper usually includes the frequency of exposure (sometimes not the exact frequency, but only the designation "microwave" or a frequency band in the microwave region), the incident-power density of the radiation, the duration of exposure, and animal species. Very little, if any, information is given on how the animals are exposed, field characteristics, energy absorption, how control animals are maintained, and other important experimental design matters required for meaningful research. In most cases the bulk of the paper presents many biological changes with little description of the techniques used to measure the observed alterations. Where effects on humans are reported, exposure frequency is usually designated in such broad terms as microwaves, sometimes the range of levels measured within the general area, and sometimes the length of time the person has worked in the area are given. Little or no discussion of how the exposed and control groups are constituted and the possible presence of other environmental factors, both chemical and physical, is provided. Most reported results are subjective, and techniques used to obtain the results are often not given.

In spite of these difficulties with Soviet and Eastern European research, this large volume of data has been an important driving force in the United States in producing concern over the biological effects of microwave radiation and in generating research to evaluate the significance of microwave exposure. Attempts to duplicate some of the Soviet and Eastern European work by Western investigators have not obtained, in most cases, the same biological changes, but because of the lack of information in the Soviet and Eastern European literature, it is technically impossible to duplicate their research in all aspects. Attempts were usually concluded by a statement which read something similar to this: attempts to duplicate the results obtained by the Soviet or Eastern European investigators were unsuccessful, but, because of lack of information in their reports, we were unable to duplicate all aspects of their experiments.

An almost total lack of scientific interchange and cooperation with Soviet and Eastern European investigators before 1972 made the dilemma

seem insurmountable, and most American scientists considered the large volume of Soviet and Eastern European literature of little significance in evaluating the hazardous effects of microwave radiation. In 1971 the United States and the Soviet Union agreed to cooperate in health-related research areas. In March 1972 an agreement was signed between the U.S. Department of Health, Education and Welfare and the U.S.S.R. Ministry of Health to cooperate in the area of cancer, heart and lung disease, and environmental health. The directors of the National Cancer Institute, National Institute of Heart and Lung Diseases, and the National Institute of Environmental Health Sciences were appointed to work with Soviet counterparts to develop cooperative plans for research in each of the specified areas. In January 1973 a Program of U.S.-U.S.S.R. Cooperation on the Problem of Environmental Health Research was signed. This original program did not include microwave bioeffects, although the United States at this time emphasized its interest in including microwave bioeffects in the program.

At a meeting in March 1974 it was agreed to include microwaves in the cooperation using the following steps:

1. Exchange of national literature surveys on the biological effects of nonionizing (microwave) radiation
2. Two to four specialists to be exchanged before the end of 1974 to familiarize themselves with current research in each country
3. Possible cooperative research to be discussed in December 1974 during a Symposium in Moscow

Concise surveys of national literature were exchanged and the Soviet Union reviewed only research during 1970-1972. They emphasized general population exposure and did not include significant research from the occupational institutes. In May 1974 five scientists from the United States traveled to the Soviet Union and visited both the General and Municipal Hygiene Institute in Kiev and the Industrial Hygiene and Occupational Diseases Institute in Moscow. These two Institutes are responsible for occupational and general population microwave-exposure standards in the Soviet Union. During this time scientific papers were presented on research being performed in both the United States and the Soviet Union. In February 1975 three Soviet scientists visited the United States, and in September 1975 a meeting was held in Kiev to develop a cooperative program. The formal agreement to cooperate in the area of the biological effects of microwave radiation was signed in October 1975. Since 1975

there have been yearly exchange visits by scientists from both countries.

Other important contacts with Soviet and Eastern European countries took place at the time the cooperation was being developed. On October 15-18, 1973 an International Symposium on the Biological Effects and Health Hazards of Microwave Radiation was held in Warsaw, and provided important contact with researchers from the Soviet Union and other Eastern European countries. Scientists from the Soviet Union, Poland, Czechoslovakia, and the German Democratic Republic participated, and symposium proceedings provide an initial reference from which to discuss Soviet and Eastern European research.¹

Since 1973 the contacts with Soviet and Eastern European investigators have increased. Exchange visits to laboratories have become more numerous, and participation by Soviet and Eastern European scientists in international symposia have increased during the past five years. Literature and scientific information not previously available have been exchanged and some of this more recent research is discussed in this paper.

SOVIET RESEARCH

I visited institutes concerned with general and communal hygiene and with industrial hygiene and occupational diseases. These institutes have responsibilities similar to those of the Environmental Protection Agency (EPA) and National Institute for Occupational Safety and Health (NIOSH). They have the responsibility for health-effects research and for developing safety standards. The Soviet Academy of Science Institutes perform more basic, sophisticated research on many of the same problems under investigation by the Ministry of Health Institutes. Relevant information is used by the Ministry of Health to develop standards. In general, the Academy of Science Institutes are much better equipped than the Ministry of Health Institutes and the Academy of Medical Science Institutes, and supposedly have the best scientists. I did not always find this to be the case.

Most institutes of occupational hygiene and industrial diseases have clinics where those who work under conditions suspected to be hazardous are examined periodically to determine if harmful effects are occurring. This explains to some degree the large amount of human bioeffects data reported by the Soviets which are not in most cases from epidemiological studies with experimental and control groups as closely matched as possible, but from examinations in these clinics. The possibility exists that other

factors in the workplace could produce the effects reported. This also explains to some extent the interest the Soviets have in combinations of microwave, ionizing radiation, and noise in animal experiments.

The laboratories carrying on research into the biological effects of microwaves I visited all noticeably lacked engineering and physicist support, but appeared capable in the biological sciences. This lack of engineering support and knowledge about microwave radiation is evident from their exposure, measurement, and instrumentation capabilities. I shall discuss two examples of microwave exposure observed during a visit to the Soviet Union in 1974.

The first arrangement was observed in one of the general and communal hygiene institutes. The exposure room had no absorber on the walls to prevent reflections from objects in the room and walls. The microwave source was a standard diathermy unit radiating at a frequency of 2,375 MHz. Pregnant rats (10 to 15 in number) were all exposed in a wooden box with a plexiglass front with food and water containers. The power density was measured using a PO-1 Soviet instrument which consists of a receiving horn, thermistor, and power flux meter. The PO-1 instrument is the standard instrument for measuring power densities in the microwave frequency range. Control animals were placed in the same room in a similar box behind the exposed animals. The exposure usually ranged from 0 to 100 $\mu\text{W}/\text{cm}^2$. No specific absorption rates were measured in any of the experiments which we observed because they say they are exposing at low levels where no heating of tissues occurs.

A second exposure room was in an occupational hygiene and industrial diseases institute in Moscow from which a large volume of literature has been published and from which the occupational exposure standard of 10 $\mu\text{W}/\text{cm}^2$ was generated. A standard gain horn was used as the irradiator. We were told that no measurements were made of the fields at the specimen location because the specimens were far enough from the horn to be in the far field. They determined their exposure intensity by calculating the values using free field equations in the far field of a radiator. The walls of the room were not covered with microwave absorber but absorber was located behind the exposed animals. The animals were separated in plexiglass boxes but were not spaced far enough apart to prevent scattered irradiation from one animal from impinging upon adjacent animals. In this experiment, control animals were neither located in the same room nor handled the same way as the experimental animals. Again, no energy-

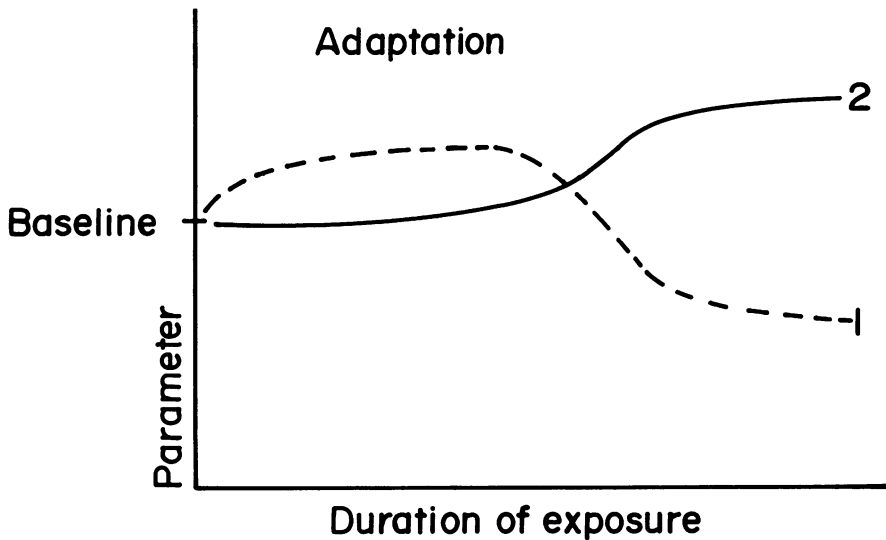
absorption measurements were made, although exposures were in the low milliwatt/square centimeter range because they considered these levels to be nonthermalizing.

Contrary to the lack of engineering and physical scientific expertise associated with their microwave research, the biologists appeared capable of performing the required research. The major constraint in their biological capability seems not to be due to the quality of scientists but to the lack of up-to-date analytical equipment and instrumentation. Many of their laboratories are very limited in the amount of equipment, and much of what they have is obviously very old.

Recent visits to the Soviet Union have shown significant improvement in their exposure systems. Much of the improvement is probably due to recent visits to the United States and to observation of exposure systems in this country. The two institutes discussed above now have exposure rooms with absorbers on all walls and, in some cases, where multiple animals are being exposed, the exposure is from above. They also realize that much of their earlier electroencephalographic data, taken with metal implanted electrodes, are not valid because of potential artifacts produced by the interaction of the electrodes with the microwave fields.

During visits to the Soviet Union, some insight into the approach of the Soviet health institutes to studying this problem has been obtained. They believe that the more complex the biological system the greater the possibility of it being affected at low levels of exposure. Therefore, the health institutes in most cases use whole animal systems in their studies. They believe it is more important to obtain effects on different species of animals to extrapolate results from animal to man rather than to use *in vitro* or more simple systems to obtain basic mechanism of interaction data to enable such an extrapolation.

Adaptation is also an important consideration in their research. They state that human beings evolved under certain environmental conditions. Changes in these environmental conditions, increase or decrease, affect human beings, but human beings have adaptive capabilities which enables them to adapt to certain levels of changes without harmful effects. Levels greater in magnitude than those adaptive levels are defined as hazardous. Some of their research reports a biphasic change in a given biological parameter with increasing exposure time (see figure), which they explain by suggesting that the animal is attempting to adapt to microwave stress and overcompensates to the point that the change reverses direction (curve



Two suggested adaptation processes in response to microwave exposure.

1). Another form of adaptation which they discuss involves the idea that in the initial stages of exposure, animals can compensate for the microwave stress without changes in biological indicators. After a period of time, the animals can no longer adapt, and biological changes are then observed (curve 2).

Most Soviet research is performed, therefore, at low levels of exposure for long exposure duration. They consider that power densities above 1 mW/cm.² are high enough to produce harmful effects, and see no reason to perform research above this level. When we respond that in some of our experiments we see no significant changes at exposure levels above 1 mW/cm., their answer is that we did not expose long enough. Most of their low level experiments are for six months to a year, while American experiments are usually in terms of a few weeks. Long-term experiments using low levels of microwaves must be performed in the United States before the Soviet results can be verified or refuted.

SOME REPORTED BIOLOGICAL EFFECTS

Before reporting on Soviet and other Eastern European biological effects, the results of the U.S.-U.S.S.R. cooperative program should be

briefly reviewed. In the early stages of the cooperative program, it consisted mainly of an exchange of results on projects related to the central nervous system and behavior. American research consisted primarily of acute experiments with exposure levels generally of 5 mW/cm.² and above, while Soviet experiments were long-term, low-level experiments at 500 μ W/cm.² and below. At the end of the first year of the cooperation, the Soviets reported changes in bioelectric brain activity at 10, 50, and 500 μ W/cm.² in rats and rabbits exposed for 7 hours/day for 30 days to 2,375 MHz. radiation. Levels of 10 and 50 μ W/cm.² stimulated brain activity, while 500 μ W/cm.² suppressed activity as seen from an increase of slow, high amplitude Δ -wave in rabbits. At 500 μ W/cm.² a decrease in capacity for work, in investigative activity, and sensitivity to electric shock threshold in rats were reported. Research by American investigators on rats exposed to 5 mW/cm.² for shorter durations of exposure to 2,450 MHz. radiation showed no statistical difference in electroencephalogram, no change in locomotive activity in a residential maze, and no change in performance on a fixed ratio schedule of reinforcement below 5 mW/cm.² (0.5 and 1.0 mW/cm.²) but a trend toward decrease in performance at 5 mW/cm.² and a large decrease in performance at 10 and 20 mW/cm.²

It became obvious that, except for our being more familiar with their experimental design, we were no closer to understanding differences between American and Soviet results. It was then decided to perform a duplicate experiment to determine whether similar effects could be observed. Rats were exposed from above for seven hours/day, seven days/week for three months to 500 μ W/cm.². Dr. Richard Lovely of the University of Washington, project leader on the duplicate project, spent four weeks in the Soviet Union to observe the behavioral and biochemical tests performed on the animals. The American study found a drop in sulfhydryl activity and blood cholinesterase as reported in the Soviet study. Blood chemical analyses at the termination of three months exposure indicated that exposed animals, relative to controls, suffered from aldosteronism. The latter interpretation of the high sodium-low potassium levels found in the blood was confirmed by necropsy and histopathologic study of the adrenal glands, revealing that the zona glomerulosa was vacuolated and hypertrophied. In addition, *all* behavioral parameters assessed at the end of three-month exposures revealed significant differences between groups in the same direction as those reported in the Soviet study, i.e., increased threshold to footshock detection, decreased activity in an

TABLE I. FREQUENCY OF HYPOTONIA IN PERSONNEL EXPOSED TO MICROWAVES ACCORDING TO SOVIET AUTHORS

| <i>Author and year</i> | <i>No. of individuals examined</i> | <i>Frequency of hypotonia %</i> |
|--------------------------------|------------------------------------|---------------------------------|
| Kerovski, A.A., 1948 | 87 | 38 |
| Osipov, Ju A., 1952 | 108 | 30 |
| Shipkova, V.A., 1959 | 110 | 20 |
| Orlova, A.A., 1960 | 525 | 26-33, various groups |
| Uspenskaja, I.V., 1961 | 100 | 30 |
| Volfavskaja, R.N. et al., 1961 | 101 | 27-45, various groups |
| Frelova, L.T., 1963 | 172 | 25.6 |
| Komarov, F.I. et al., 1963 | 53 | 22.6 |
| Gembricki, E.V., 1966 | 210 | 14 |

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open field, and poorer retention of an avoidance response when reassessed following conditioning. This replication of the Soviet results at 500 $\mu\text{W}/\text{cm}^2$ emphasizes the need for additional long-term, low-level microwave bioeffects research.

Effects on human beings. Most of the bioeffects research in Eastern European countries is performed by Soviet and Polish investigators. A small amount of data, mainly effects on human workers, have been reported by Czechoslovakian scientists. Reported effects on personnel occupationally exposed to microwaves has been summarized by Baranski and Czerski² and are shown in Tables I and II. These results come primarily from two groups in the Soviet Union who have done extensive clinical studies on microwave workers. Baranski and Czerski² refer to the groups as the Moscow group and the Leningrad group. The Moscow group has reported changes in white blood cells, although no characteristic changes in peripheral blood have been found. Blood proteins, serum histamine content, and enzyme activity have been reported but they returned to normal levels after a few days of rest. The influence of microwaves on the autonomic nervous system was evidenced by reports of vagotonia, bradycardia, and hypotonia. With periodic exposure to power density levels of 0.1 to 10 mW/cm^2 , marked changes in cardiac rhythm (variability or pronounced bradycardia) were reported. Hypotonia was one of the more pronounced effects (Table I). Prolonged exposure to power density levels from 0.01 to 0.1 mW/cm^2 produced effects similar to those

TABLE II. COMPLAINTS OF MICROWAVE WORKERS (%) ACCORDING TO VARIOUS AUTHORS

| <i>Author and year</i> | <i>Headaches</i> | <i>Fatigue dispro- portional to effort</i> | <i>Sleep distur- bances</i> | <i>Irritability</i> | <i>Abnormal sweating</i> | <i>No. of workers examined</i> |
|--|------------------|--|-------------------------------------|---------------------|------------------------------|--|
| Uspenskaja, N. V., 1963 | 37 | 31 | 29 | 9 | 7 | 100 |
| Sadchikova, M. N., 1963 (various groups) | 12-39 | 20-35 | — | 8-27 | — | 447 |
| Kilmkova-Deutschova, 1963 (Czech.) | 43 | 39 | 35 | — | — | 73 |
| Serel, 1959 (U.S.S.R.) | 43 | 4 | 45 | 10 | — | 103 |
| Tjagin, N. V., 1966 (U.S.S.R.) | 33.5 | 46.2 | 25.3 | 9.6 | 25.5 | 573 |
| Ramzen-Evdokimov and Sorokin, 1970 (U.S.S.R.) | 44 | 29 | 35 | 36 | 25 | 155 |
| <i>Controls</i> | | | | | | |
| Uspenskaja, 1963 | 15 | 22 | 2 | 10 | — | 100 |
| Sadchikova, 1963 | 8 | 10 | — | 8 | — | 100 |
| Tjagin, 1966 | 10.8 | 5.9 | 8.7 | — | 2.7 | 184 |
| Ramzen-Evdokimov and Sorokin, 1970 | 7 | 8 | 3 | — | 4 | 50 |

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mentioned above. The symptoms were less pronounced and reversible after periods of rest.

The Moscow group also reports that chronic exposure leads to a neurocirculatory syndrome in three stages. The first symptoms are reversible and include changes in blood pressure and cardiac rhythm. In the second stage, cardiovascular changes become more pronounced, and electroencephalographic changes which indicate disturbance of the diencephalon were also found. Hyperactivity of the thyroid is also indicated. A condition defined in Soviet literature as an "asthenic state" may develop. Such subjective complaints as headaches, excitability and irritability, fatigue, and pains around the cardiac region (Table II) characterize this stage. The third stage of effects is characterized by a greater magnitude of change in the complaints and symptoms and additional electroencephalographic changes.

The Leningrad group discusses their findings in terms of an acute microwave syndrome and a chronic microwave syndrome. The acute syndrome is characterized by subjective complaints of headaches, nausea, vertigo, and sleep disturbance. Hypertonia, changes in cardiac rhythm, skin rash, and decrease in amplitude of electroencephalographic alpha waves are also characteristic. Symptoms are transient and disappear completely after rest. The chronic syndrome is expressed in terms of adaptive processes. Subjective complaints of headaches, fatigue, and the like occur during the first three months of exposure, and reappear about the sixth to eighth month. After the first year a period of adaptation occurs which varies in duration. The complaints and symptoms of neurovegetative disturbances reappear after five years of work (chronic overexposure syndrome). This chronic overexposure syndrome is characterized by complaints of headaches, irritability, sleep disturbances, weakness, decrease of sexual activity, pains in the chest, and a general unhealthy feeling ("a general feeling of ill-being").

A large number of Polish clinical studies confirm the Soviet findings on the periodicity of the subjective complaints for exposures to 1 to 10 mW/cm.².² Subjective complaints were exactly the same as described by the Soviet authors (Table II), and were observed in up to 70% of persons exposed to the 1 to 10 mW/cm.² power density levels. The few Czechoslovakian reports (Klimkova-Deutschova¹ and Serel²) agree with the Soviet authors (Table II). They also discuss symptoms in terms of a "neurasthenic syndrome."

TABLE III. SOME DATA ON THE EXPOSURE OF MAN AND ANIMALS TO MICROWAVE FREQUENCY FIELDS (ARRANGED ON INTENSITY SCALE)

| <i>Power density</i> | |
|--------------------------|--|
| W/cm. ² | <p>1 Eye cataracts in dogs after exposure for three to five hours</p> <p>800</p> <p>600 (L,M) Pain sensation during exposure</p> <p>300 Brief increase in blood pressure; after 20 to 60 minutes marked decrease (cat, rabbit, dog)</p> <p>200 (L) Malformation of offspring after exposure for 10 to 15 minutes (chicken eggs, $\lambda = 12.6$ cm), death of cats and rabbits (t = 20 to 60 minutes). Reduction of redox in tissue</p> |
| mW/cm. ² | <p>100 (M) Increase in blood pressure with subsequent marked decrease; in case of chronic exposure—stable hypoxia. Stable morphologic changes in the cardiovascular system. Bilateral cataracts.</p> <p>40 (L) Increase in blood pressure with subsequent marked decrease; multiple hemorrhages, $\lambda = 3$ to 10 cm, in liver (dilatation of vessels and hemorrhages $\lambda = 10$ cm.). Increase in blood pressure of 20 to 30 mm. Hg (exposure for 0.5 to 1.0 hour).</p> <p>10 (M) Changes in conditioned reflex activity, morphological changes in cerebral cortex (L). Vague shifts in blood pressure (exposure time 150 hours), change in blood coagulability. Hyperplasia of liver cells, $\lambda = 3$ to 10 cm. (chronic exposure). ECG changes (wave-lengths other than DTsV—expansion not given). Change in receptor apparatus.</p> <p>5 Threshold intensity at which there are changes in the testis and blood pressure changes (multiple exposure). Brief leukopenia and erythropenia. Darkening of the crystalline lens.</p> <p>3 (M) Decrease in blood pressure, tendency to quickening of pulse, fluctuation of cardiac blood volume.</p> |
| mW/cm. ² | <p>1 (M) Decrease in blood pressure, tendency to quickening of pulse, insignificant variations in cardiac blood volume. Decrease in blood pressure level, decrease in ophthalmotone (t: daily, 3.5 months). Disadaptation, disorders of immunological protection control mechanisms (L).</p> <p>400 Depression of secretions in dogs</p> <p>300 (L,M) Some changes in the nervous system in case of exposure for 5 to 10 years</p> <p>200 Changes in function of neurons in dogs</p> <p>100 (L) Tendency to decrease in blood pressure with chronic exposure</p> <p>40 (L) Tendency to decrease in blood pressure with chronic exposure</p> |
| μ W/cm. ² | <p>20 (M) Thinning of pulse, tendency to a decrease in arterial pressure. Cases of body sensitivity observed. Well-expressed increase in skin temperature in persons earlier exposed.</p> <p>M Data applies to man—all other to animals</p> <p>L Lowest power density indicated by authors</p> |

Source: Minin, B.A.: *Microwaves and Human Safety*. U.S. Joint Publication Service, JPRS 65506. August 20, 1975.

TABLE IV. SOME RESULTS OF EXPERIMENTAL STUDIES ON THE BIOLOGICAL EFFECTS OF VERY LOW INTENSITY MICROWAVES (UP TO 150 $\mu\text{W}/\text{cm}^2$)

| <i>Investigated function</i> | <i>Radiation intensity $\mu\text{W}/\text{cm}^2$</i> | <i>Character of changes</i> | <i>Investigator</i> |
|------------------------------------|---|--|-------------------------------|
| Body weight | 150 | Lag in weight (chronic experiment) | V. V. Markov |
| Arterial pressure | 150 | Biphasic course with marked hypotension (chronic experiment) | V. V. Markov |
| Reproductive function | 150 | Decreased fertility, decreased litter size, increased number of defective progeny, increased embryonic mortality etc. (chronic experiment) | A. N. Bereznitskaya et al. |
| Central nervous system | 10-20 and higher | 1. EEG changes with predominant synchronization (acute experiment) | Z. V. Gvozdkova et al. |
| | 150 | 2. Bivariant shifts with predominance of activation (acute experiment) | |
| | 150 | 3. Bivariant shifts in the subcortical-basal structures (chronic experiment) | |
| Electromyography | 150 | Increased electrical activity of active unit | V. V. Markov |
| Hypothalamus-adrenal cortex System | 150 | 1. Weight change of endocrine glands (hypophysis adrenals) | N. K. Demokidova |
| | | 2. Change in the neurosecretory function of the hypothalamus. | |
| | | 3. Tendency for increased levels of norepinephrine in the adrenals | |
| Metabolism | 150 | Changes in water and electrolyte metabolism (Na, K, water, and total nitrogen excretion) | N. K. Demokidova |
| Immunology | 150 | Inhibition of neutrophils phagocytic activity | A. P. Vokova and V. V. Markov |

Source: Gordon, Z. V., editor: *Biological Effects of Radiofrequency Electromagnetic Fields*. U.S. Joint Publication Service, JPRS 65506, August 20, 1975.

TABLE V. RADIOFREQUENCY STANDARDS FOR OCCUPATIONAL EXPOSURE TO CONTINUOUS WAVE FIELDS (WORKING DAY)

| Country | Radiation frequency (GHz.) | RFR intensity (mW/cm. ²) |
|----------------|-------------------------------|---|
| United States | | |
| ANSI* | 0.01-100 GHz. | 10 |
| OSHA† | 0.01-100 GHz. | 10 |
| ACGIH‡ | 0.1 -100 GHz. | 10 |
| Great Britain | 0.3 - 30 GHz. | 10 |
| Canada | 0.1 -100 GHz. | 10 |
| | | (1 proposed) |
| Sweden | 0.3 - 3 GHz. | 1 |
| Poland | 0.03-300 GHz. | 0.2 |
| Czechoslovakia | 0.3 -300 GHz. | 0.025 |
| U.S.S.R. | 0.3 -300 GHz. | 0.01 |

*American National Standards Institute

†Occupational Safety and Health Administration

‡American Congress of Governmental Industrial Hygienists

Note: Some countries have more permissive intensities for shorter exposure times and more restrictive intensities for exposure of the general population.

Effects on animals. A compilation of many Soviet reports on the effects of microwave radiation on animals is presented (Tables III and IV). Both Soviet and Polish investigators report behavioral, central nervous system, cardiovascular system, biochemical, endocrine and metabolic, hematological and reproductive functional changes in animals. All of these reported effects (Tables III and IV) were observed at power densities equal to or less than 10 mW/cm.² and many of the effects were observed at power densities less than 1.0 mW/cm.² Biological changes in both human beings and animals have been reported below 500 μ W/cm.²

MICROWAVE EXPOSURE STANDARDS

The current standards for occupational exposure to continuous wave fields for a working day show large differences between Soviet and other Eastern European countries and western countries (Table V). Although Gordon³ also presents a permissible exposure level of 1 μ W/cm.² for the general population as well as the 10 μ W/cm.² for occupational exposure, the Soviet Union does not have at this time a "legal" permissible general population exposure levels. However, the Institute of General and Communal Hygiene in Kiev, under the direction of the Soviet Ministry of Health, has proposed a general population standard for microwave exposure of 5 μ W/cm.² (Table VI). This maximum permissible level is enforced at present and will become an official standard at the end of this

TABLE VI. MAXIMUM ALLOWABLE LEVELS (MAL) OF ELECTROMAGNETIC ENERGY IN THE HUMAN SETTLEMENTS

| <i>Radiowaves ranges</i> | <i>Limits of ranges (frequency, wavelength)</i> | <i>MAL of EMW energy on the dwelling territory</i> |
|--------------------------------|---|--|
| Long waves | 30-300 kHz. (10-1 km.) | 20 V/m. |
| Middle waves | 0.3-3 MHz. (1-0.1 km.) | 10V/m. |
| Short waves | 3-30 MHz. (100-10 m.) | 4 V/m. |
| Ultrashort waves | 30-300 MHz. (10-1 m.) | 2 V/m. |
| Microwaves 24-hour exposure | 300 MHz.-300 GHz. (1 m.-1 mm.) | 5 μ W/cm. ² |

year unless reasons not to accept it are presented to the Ministry of Health.

Differences in the meaning of standards exist between the Soviet and other Eastern European countries and the United States. First, the maximum permissible exposure level is set at the value where no biological effects occur. No differentiation between effects and hazards is made in setting their standards. Although most of their reported effects at low levels are reversible and return to normal levels after a period of time, and although they recognize that a difference between an effect and a hazard might exist, these facts are not considered in setting maximum permissible levels. Second, the occupational and general population standards in the Soviet Union and other Eastern European countries are not applicable to persons in military and space programs. This enables them to avoid the problems of restrictive use in high priority applications when setting very stringent maximum permissible exposure levels for lower priority situations. This exclusion of individuals in certain work activities is of course impossible in the United States if harmful effects do in fact occur at a given level and duration of exposure. Unfortunately, with the data base that exists today, this "safe" level cannot be set with certainty for either the general population or occupational groups.

SUMMARY

The Soviet and other Eastern European countries have published much information on the biological effects of microwave radiation. Almost no contact between Eastern European and Western scientists on this problem existed prior to 1972, when the cooperative agreement on environmental

health was signed with the Soviet Union. Since 1972 scientific exchanges have occurred on an annual basis with some American scientists staying as long as six weeks to observe Soviet research. Other exchange programs between Polish investigators and American agencies have taken place over the past several years. The exchanges have provided us with a better insight into research in these countries.

Because of my direct involvement with the U.S.-U.S.S.R. cooperative program, this paper has concentrated on Soviet research. These institutes stress human clinical studies and long-term, low-level effects on whole animal systems. They report an "asthenic syndrome" in occupationally exposed workers, characterized by headaches, irritability, fatigue, sleep disturbances, pains in the chest, and a general feeling of ill-being. Polish and Czechoslovakian investigators report the same human effects as the Soviet investigators. Reports of animal studies by Soviet and Polish investigators at exposure power densities of 10 mW/cm.² and below include effects on central nervous system, behavior, cardiovascular system, hematology and blood biochemistry, immunology, endocrinology and metabolism, and reproductive function.

Maximum permissible exposure levels in the Soviet Union and other Eastern European countries and accepted safe levels in the United States differ drastically. For a full working day of exposure, the Soviet standard is 1,000 times less than that presently accepted in the United States. However, the Soviet level is set where supposedly no biological changes occur, even if reversible. No evaluation of the biological changes in terms of harmful consequences is incorporated into the standard. It should also be noted that certain programs (military and space) do not adhere to the same requirements as those set by the Soviet Ministry of Health.

Questions and Answers

DR. RUSSELL CARPENTER: Dr. McRee, were methods of measuring the microwave levels of power what you showed us, how can we really take any stock in what they offer? When they say "low levels" and one measures it with plaster walls and no anechoic chambers, I do not know what their device was. Do you think their measurements are very reliable?

DR. McREE: The PO-1 meter that they used is a reliable device for measuring incident power density. If they were exposing the animal at 1 or 10 mW/cm.² and one had a 10 to 100 amplification factor or error factor in

the measurement, obviously it could be a high level thermal effect. But they report biological changes at $10 \mu\text{W}/\text{cm}^2$ and I just cannot see that much error. I would estimate a factor of 10 in that particular exposure. Dr. William Guy and I had some meters over there but we, unfortunately, were not allowed to take some measurements that we wanted, but one can look at the reflectivity and so forth at $10 \mu\text{W}$ incident and see no greater increase than about $100 \mu\text{W}$ to 1 mW . They do not report specific absorption rates. In fact, I have never seen them measure or attempt to measure these. Because they say that at their levels they have no heating. I could not measure a specific absorption rate at $10 \mu\text{W}/\text{cm}^2$. So they don't really feel there is a need. They have improved their exposure systems. The plaster walled room shown in the slide with the animal in front of the diathermy unit has now been replaced by a standard gain horn irradiator, animals in the far field, and microwave absorbers on the walls. We have done a duplicate project with them. At exposure to $500 \mu\text{W}/\text{cm}^2$ for seven hours per day, seven days a week, for three months, we examined blood chemical and behavioral changes. Behavioral changes measured were almost identical to those measured by Shandala's group. This work at the University of Washington by Dr. Lovely, I think, amplifies the problem, or rather the realities, of the situation. We must do some chronic low level work, and we might be surprised. I think that Lovely and Guy were probably more surprised than anyone else that they found those results at a half mW/cm^2 .

MR. EDWARD L. HUNT (Walter Reed Army Institute of Research): The Russians have begun to adopt some of the same essential kinds of specifications that we use. For example, Tyazhelov in Helsinki has used watts per kilogram, which is our specific absorption rate (SAR).

DR. McREE: They have begun to do this, particularly where it is relevant, where they think they can measure specific absorption rates. Of course, one can measure such rates in any condition if one just exposes at a higher power density level and extrapolates down to the low level at which one tries to do the experiment. But one encounters heat transfer conduction problems because one is basically measuring the temperature.

MR. GEORGE WILKENING: Is it a valid argument not to use SAR because of heat? One doesn't necessarily have to have it, does one?

DR. McREE: One must measure the fields or the temperature and unless the BRH field probe is as good as they say, and is made available....

DR. JAMES FRAZER: Dr. McRee, you are only halfway to the solution.

When you measure SAR, you indeed measure the electric field in the tissues.

DR. McREE: I agree, but presently most people obtain SAR from temperature measurements. Most people do not have a field probe with which to measure local fields. Most do have a temperature measuring device.

DR. DON R. JUSTESEN: Does this not imply that human beings are more sensitive to weak electromagnetic fields than the best sensors that the engineers can devise? Presumably, it is beyond the capability of the engineers to detect these fields, while the human being not only reacts to them but suffers terribly from all manner of neurasthenic illness. Is this not the implication?

DR. McREE: You are trying to make a point. What is it?

DR. JUSTESEN: It is possible that the central nervous system is the most sensitive of all instruments to weak radiofrequency fields—that we could throw away our power-density meters and more accurately index the presence of extremely weak but nonetheless harmful fields simply by counting the number of factory workers or embassy employees with neurasthenic symptoms.

MR. WILKENING: To use the incidence of a malady in which the role of microwaves is at best conjectural as an index of field strength would certainly beg the causal question.

DR. JUSTESEN: Precisely my point. I spoke with tongue in cheek. Although I do not disparage the sensitivity of the nervous system to electromagnetic fields, I do disparage the tendency of some individuals to blame any manifestation of disease on the microwaves. A good case in point is Dr. Milton Zaret's assertion⁵ that over-the-horizon radar beams from the Soviet Union are responsible for the high incidence of cardiac disease and heart failure in the North Karelia district of Finland.¹ There is little doubt that the Soviet-launched radiation incident on the inhabitants of this district is unmeasureably small—much less than the microwave radiation emitted by the human body. One must disparage the assertion of an etiological role of any agent in any pathological condition in the absence of measurement, correlation, and verification.

DR. McREE: I understand the point Dr. Justesen makes, and it is a valid one. We should not jump to the conclusion that health effects found in persons who might be in a location where microwaves are present are due to the microwave radiation. It is important to characterize the microwave

radiation levels and any other environmental factors which might be present. However, the Soviets can measure accurately microwave levels in the low $\mu\text{W}/\text{cm}^2$ range and have conducted long-term experiments on animals at these levels. Reversible biological changes have been reported in these experiments at power density levels as low as $5\mu\text{W}/\text{cm}^2$.

DR. JUSTESSEN: Dr. Zorach Glaser, formerly with the Department of the Navy, and now in transition from the National Institute of Occupational Safety and Health to the FDA's Bureau of Radiological Health, is owed a debt of gratitude by all physicians, biologists, and biological engineers who labor in the radiofrequency field. For years Dr. Glaser has performed the nearly thankless task of cataloging, updating, and disseminating titles and sources of published information on biological effects of radiofrequency fields. His current compendium exceeds 5,000 titles. Someone should acknowledge Dr. Glaser's onerous but highly useful labor.

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